

REMARKS/ARGUMENTS

Claim Amendments

Before this response, claims 1-8, 16-18, and 21-27 were pending in this application. By this amendment, no claims are cancelled and new claims 41-52 are submitted; accordingly claims 1-8, 16-18, 21-27, and 41-52 are now presented for examination in light of the remarks below. No new matter has been added; support for the amendments and the new claims is found throughout the application.

Amendments to the Specification and Drawings

Amendments to the specification and drawings have been made to correct clerical errors and to change a reference numeral in Figs. 2, 3, and 4 from "140" to "240" to eliminate any possible confusion that could have resulted from using the same reference numeral for the microlens structure in Fig. 1 and the spacer structure in the other figures.

Summary of the Office Action and this Response

In the outstanding Office Action, claims 1-8, 16-18, and 21-27 were rejected only under 35 U.S.C. §103(a) as being unpatentable over Kravitz in various combinations with other references. Applicant respectfully traverses these grounds of rejection as set forth below.

Rejections Under § 103

In the Office Action of February 3, 2003, the Examiner rejected previously pending claims 1-8, 16-18, and 21-27 under 35 U.S.C. §103(a) citing Kravitz et al. ("Kravitz" 5,790,730) in various combinations with Meissner ("Meissner" 5,846,638), Stegmueller et al. ("Stegmueller" 5,195,150), Funami et al. ("Funami", 5,200,010), and Lur et al. ("Lur", 5,449,630).

In response, applicant will show that Kravitz does not disclose a first (spacer) layer and a second (microlens) layer as claimed. None of the other references disclose this structure, and therefore the various combinations do not disclose the claimed structure in which the microlens layer has a higher index of refraction than the spacer layer as claimed in claims 1 and 16. All other claims are dependent upon claims 1 and 16, and therefore follow.

The Examiner's main reference is Kravitz, which is relied upon to show the layered structure including a second layer with microlenses. Citing Fig. 5B, col. 6, lines 65-67, and col. 7, lines 1-36, the Examiner states that Kravitz teaches a hybrid microlens comprising two

layers that are transparent at a wavelength of interest, including: a first layer that has a low index of refraction; a second layer adhered to said first layer; and said second layer having an optical focusing element formed on the surface non-adjacent to said first layer, said second layer being substantially thinner and having a higher index of refraction than the first layer.

Applicant respectfully traverses the Examiner's assertion. Although Kravitz discloses that the substrate portion 14 may comprise a layered structure formed from a plurality of layers of two or more different materials (Fig. 5B, col. 7 ln 8 et seq.), Kravitz does not teach or suggest a structure as claimed in which the second layer has a higher index of refraction than the first layer. While disclosing a range of materials in general terms, Kravitz simply does not disclose or recognize a structure in which that the second (microlens) layer has a larger index of refraction than the first layer. As discussed in more detail below, Kravitz discloses a multilayer structure, but 1) Kravitz does not in any way appreciate the significance of the optical characteristics of the layers other than the general requirement of transparency, 2) the only practical embodiments use low-index material such as plastics or glass for the outer microlens layer which indicates that Kravitz has no intention of using a higher index material for the microlens layer, and 3) Kravitz recognizes use of an antireflection (AR) coating at the interface between the substrate and the optical fiber, and on the outside of the microlens, but NOT at the interface between the substrate and the microlens layer. The absence of the AR coating at this interface strongly indicates that Kravitz teaches away from applicant's claimed invention: particularly the absence of the AR coating practically requires the substrate and the microlens layer to have nearly identical indexes of refraction, otherwise, a very significant undesirable Fresnel reflection loss would be suffered at the interface between the two layers of differing refractive indices.

The claimed indexes of the first and second layers provide significant advantages including smaller wafer stack thickness, large optical beam diameter, high optical performance, fast etching of the microlens surface, reduced sag, and lower cost. For example, the larger index of the refraction of the second layer advantageously allows a smaller, thinner microlens to be formed, which has advantages including reduced manufacturing time and cost, a thinner wafer structure, and reduced spherical aberrations (for example, a dramatic reduction of from 0.43 dB to 0.002 dB in one case). The low index of refraction of the first layer advantageously provides greater beam expansion (described at page 2, lines 10-18), which is useful in wafer stacking

technology at least in part because the diameter of the collimated beam determines the collimated distance of the beam, and a large beam diameter allows long working distances and low diffraction loss.

The absence of the AR coating at the layer interface in Kravitz shows that the layers contemplated by Kravitz must have similar indices of refraction.

Kravitz discloses that anti-reflection coatings may be formed or deposited onto the bottom of the cavities 44 (and also on the microlenses 16) to reduce a reflection component of the light beam 36 (col. 9, lines 37-40). The fact that Kravitz specifies AR coatings on both outer surfaces but not the interface strongly indicates that the two materials have nearly the same index of refraction in order to avoid Fresnel losses that would otherwise appear at the interface. For example the reflection loss at a glass-silicon interface without an AR coating is about 15%, which is very significant. For reference, the reflection loss at a glass-air interface without an AR coating is about 4%, which is much smaller. If Kravitz had contemplated layers with two different indexes of refraction, Kravitz would have somehow provided AR coatings at the interface because it would otherwise cause much higher loss than the loss at the outer surfaces. Therefore, it is clear that claim 16 and new claim 41, both of which specifically claim the AR coating in the context of a structure in which the second (microlens) layer has a higher index of refraction than the first layer, are not made obvious by combinations of Kravitz with Meissner or any other cited reference.

The layers contemplated by Kravitz are disclosed for their mechanical properties rather than their optical characteristics

Kravitz does not disclose the claimed structure in which the second layer has a higher index than the first layer, and there is no suggestion to modify it to do so.

In the context of the discussion of the multi-layer structure in Kravitz beginning at col. 7 line 9 et seq., Kravitz teaches that the materials in the layers are chosen for their material properties such as suitability for the formation of a microlens, increased hardness, environmental resistance, adhesion, or solderability characteristics. Nowhere is it disclosed or suggested that a material be chosen for its optical characteristics other than a general transparency requirement. Particularly, Kravitz discloses "For example, in FIG. 5b, the first layer 30 comprises a

transparent material well-suited to the formation of a refractive microlens 16". (col 7, lines 18-19). Kravitz discloses:

"The use of a substrate portion 14 comprising a layered structure may have advantages by providing a first surface layer 18 in which the microlens 16 may be conveniently and inexpensively formed by an etching, molding, or replication process; while providing a second surface layer 28 having a different material characteristic such as an increased hardness or environmental resistance. The material selected for the first or second layer may also provide improved adhesion or solderability characteristics.

(Kravitz, col. 7, lines 28-36)

Therefore, the layers disclosed in Kravitz are intended to be chosen for their material properties such as convenience of inexpensive microlens formation, rather than their optical characteristics.

In contrast, applicant's claimed invention is directed to the optical characteristics of the layers, and specifically claims the indices of refraction of the two layers. It is these optical qualities that provide the claimed invention's advantages such as thinner wafer structures, reduced manufacturing time and cost, larger beam diameter, and reduced spherical aberrations. Kravitz does not disclose or suggest such a structure.

Only low index materials are suitable for the microlens fabrication process disclosed by Kravitz

Furthermore, only low index materials are suitable for the microlens fabrication process contemplated by Kravitz, therefore for practical purposes Kravitz's disclosure is limited to a microlens layer formed of a low index material. At col. 8, lines 30-55, Kravitz discloses a refractive microlens as shown in Fig. 5B formed by molding or replicating "in a transparent glass, plastic, or resinous material" (all low index material) or by etching mesas in the transparent material and then heating the structure so that the transparent material melts to form the refractive microlens. Clearly out of the materials mentioned, all are low index materials except a semiconductor, which could be a high index material. As to the semiconductor material, Applicant is unaware of any method or published report for making a refractive microlens by etching a simple circular disk in a semiconductor, and then heating it to obtain a

rounded lens shape by a mass flow of material, as Kravitz suggested. It should be mentioned that applicant is aware of a very different approach that can create rounded microlenses in semiconductors. This "mass tranport" method is exemplified in US Patent No. 5,618,474 to Liau et al. Particularly, the method disclosed by Liau involves etching an intricate pattern of mesa pillars onto the semiconductor so that the density of the etched areas is proportional to the final thickness of the microlens, and then the etched structure is heated at a high temperature. This mass transport approach can be used with any semiconductor material. During the long heating time (e.g. 100 hours), a vapor supply must flow to compensate for the decomposition of the semiconductor material. Therefore, the etching and heating methods disclosed by Kravitz at col. 8, lines 30-55 would not provide a suitable microlens layer using a semiconductor material, although those methods would produce a suitable microlens layer using glass, plastic or resinous material, all of which are low index materials.

It should be noted that all common semiconductors require processing at a very high melting temperature; for example, GaP is processed at 950° C to 1130° C. Silicon has a melting temperature of about 1421° C. If a semiconductor were to be heated to form a round lens shape on a low index spacer material, the semiconductor would probably de-bond from the spacer layer long before the microlenses can be formed, especially if an AR coating is situated between the two layers.

Therefore, all practical embodiments disclosed by Kravitz would have a low index material that approximately matches the index of a low index substrate instead of the claimed structure which includes a microlens layer with a higher refractive index than the spacer layer.

Summary of Response

All other examined claims are dependent upon independent claims 1 and 16, and therefore follow the above. Accordingly, the references whether taken separately or in combination do not fairly teach or suggest applicant's claimed invention.

In addition, it may be noted that the trenches in the second layer as claimed in claim 8 and new claim 45 are left open to allow the second layer to expand more than the first layer, to compensate for thermal expansion differences. The pertinent reference cited by the Examiner is the Lur reference, but this reference discloses creating a trench at one point during the disclosed fabrication process, which is filled in later in the fabrication process. Thus, this "trench"

disclosed by Lur is filled in the final product, and therefore would not provide compensation for thermal expansion in the final product. Accordingly, the elements of claims 8 and 45 are not disclosed in any of the cited references.

In view of the foregoing, applicant respectfully requests withdrawal of all rejections under 35 U.S.C. § 103.

New claims

Applicant submits herewith new claims 41-46 in order to present a group of independent apparatus claims that specifically claim an antireflection coating at the interface between the two layers of differing indices. No new matter has been added; support is in the previous claims and specification.

Applicant also submits new claims 47-52 to claim the invention in broader terms than claim 1 and its dependent claims, in light of the prior art.

CONCLUSION

It is believed that applicant has addressed all of the Examiner's objections as expressed in the outstanding Office Action, and accordingly requests allowance of all pending claims.

If the Examiner finds any remaining impediment to the prompt allowance of these claims that could be clarified with a telephone conference, the Examiner is respectfully requested to initiate the same with the undersigned.

In the event that additional fees are required or credit is due, authorization is hereby given to charge Deposit Acct. No. 50-0948.

Respectfully submitted,

LAW OFFICES OF JAMES D. MCFARLAND

Dated: July 8, 2003

By:



James D. McFarland, Reg. No. 32,544

Attorney for Applicant

LAW OFFICES OF JAMES D. MCFARLAND

12555 High Bluff Drive, Suite 305

San Diego, CA, 92130

(858) 509-8687

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